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# Contribution of renewable energy sources to electricity production in the autonomous community of Navarre (Spain): A review

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**Abstract**

Economic development in recent decades has been characterised by the increased use of fossil fuels. Clearly, a significant amount of this energy does not fall in line with the principles of sustainable development, either because of its contaminating effect or because of its non-renewable nature.

Today, Navarre generates around 60% of its electricity requirements by means of wind power and small hydropower stations. On the downside, Navarre's energy consumption is above average for the European Union and its economy is growing at an annual rate in excess of 5%. The Castejón (800 MW) thermal power stations, scheduled for enlargement, generate more energy than Navarre's entire wind power sector.

In terms of hydroelectric power, there are around 200 small hydropower plants in operation. In addition, the Autonomous Community of Navarre has installed a biomass plant in Sangüesa, with an installed output of 25 MW, annually generating 200 GWh through the combustion of 160,000 t of cereal straw.

In addition, Navarre, specifically Tudela, is the site of the largest solar energy plant in Spain, producing 1.2 MWp, following its connection to the grid at the beginning of the year. Two thirds of

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the 10,080 panels are arranged in a central body and the remaining third are panels pertaining to different technologists and technologies involved in research and development.


*Keywords:* Renewable energy; UE-2010 targets; Navarre

**Contents**



## 1. Introduction

Energy has become an essential utility, both for the development of economic activities and for people's quality and comfort of life. The production of electricity in Navarre in the 1980s was based solely on two types of energy: hydraulic and thermal by means of co-generation. At that time, there were numerous small hydroelectric stations, run by private individuals, who almost had to live in the station itself in order to oversee all the instruments required for production and normal operation. Accordingly, hydroelectric stations tended to disappear in view of the complexity of life for those people running them. The other energy source was the more conventional thermal type, produced by the combustion of materials. Yet these were not large plants, but rather small boilers for in-house use in companies, which sold any surplus energy [1].

Aware of its shortcomings in traditional sources of energy, Navarre turned to renewable energies, relying on water, air and sunlight to generate energy in an attempt to achieve power self-sufficiency. Accordingly, Navarre embarked upon a Renewable Energies Plan that fostered energy saving and efficiency in order to curtail demand. In turn, support was

given to technological innovations that were environmentally friendly and rendered businesses more competitive, seeking the maximum exploitation of renewable resources with a view to diversifying the supply sources and replacing the more polluting fuels [2].

There follows a breakdown of electricity power production in the Autonomous Community of Navarre, according to the system used in its generation: wind energy, hydraulic energy, photovoltaic energy, cogeneration-thermal, biomass and combined cycle plants [3].

## 2. Wind energy

The analysis of this type of energy will involve 1994 onwards, given that prior to that date there is no knowledge of any wind farm being connected to the grid. This is the type of energy upon which Navarre based its quest for self-sufficiency [4].

In terms of wind turbines, these currently number around 1110, with the largest deployments taking place in 1998 with the installation of 233 and 2000 with 190. As may be observed in Fig. 1, the growth in wind farms in Navarre has followed a steep trend, with some years even recording growth of 100% over the prior year (Fig. 2).

In 2001, 71% of the energy generated in Navarre was obtained from wind power. Today, and due to combined cycle power stations, this percentage has fallen to 28%, although this does not mean there has been a drop in the production of wind energy. The truth is that overall production has risen by 100% from 2002 to 2003 and by 50% from 2003 to 2004.

### 2.1. Meeting 2010 targets

Commissioning is scheduled for the end of 2005 of the last new wind farms in the Autonomous Community. These are specifically the Vedadillo wind farm (Falces) and the opening of the experimental wind farms of M. Torres in Lodosa and Enériz.

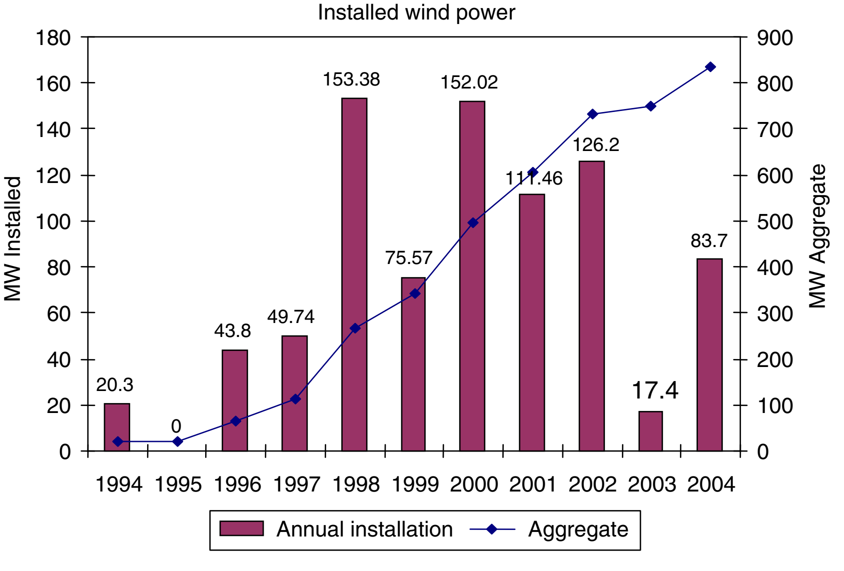



Fig. 1. Wind power.

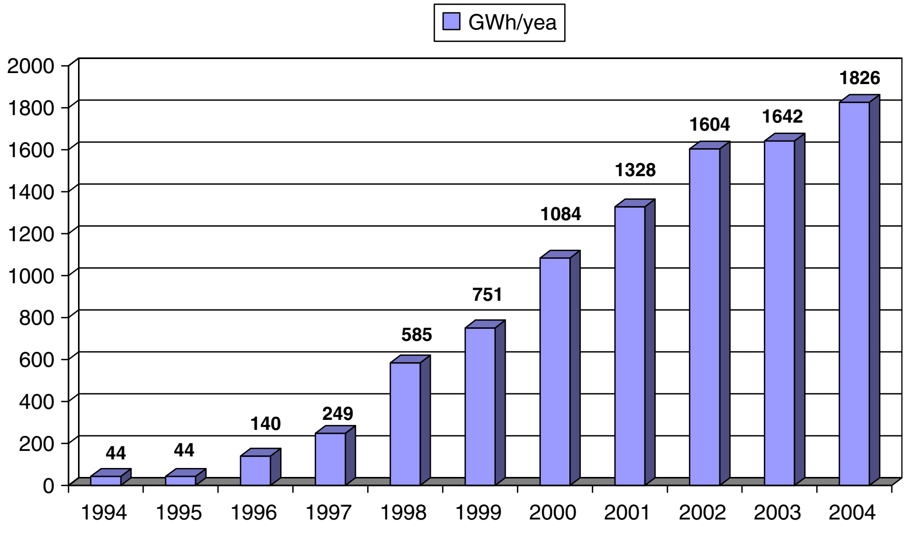



Fig. 2. Electricity generated from wind power in GWh/year.

The Vedadillo wind farm (pertaining to the EHN group, owner of 70% of the wind farms in this Autonomous Community) occupies a site located to the northwest of the town of Falces, on a broad plateau that ranges between the heights of 420 and 450 m. It consists of 33 wind turbines with an individual output of 1500 kW, arranged in three parallel rows. This amounts to a total installed power of 49.5 MW with an annual average production of 108 GWh/year.

The firm M. Torres continues to further progress in the research and development of new prototypes, using areas of the Autonomous Community for their installation accordingly. The experimental wind farm in Lodosa is equipped with three wind turbines with a rated power of 1650 kW. This accounts for a total installed power of 4.95 MW. Average annual production is around 11 GWh/year, but given that this is an experimental wind farm, output is expected to be lower. The Enériz experimental wind farm is similar to the one in Lodosa, with 4.95 MW installed and an average annual output of around 11 GWh/year, at the most [5].

Regarding wind energy, it is no easy matter to address the question of forecasts, as no more wind farms are to be installed in Navarre, although the older wind turbines will be replaced. A replacement plan has yet to be drawn up. What is certain is the installed power in 2005, thanks to the Vedadillo wind farm. The experimental wind farms have not been included, as they have not been constructed with a view to providing a continuous output, but rather for the purpose of testing and research.

## 3. Hydraulic energy

Hydraulic energy has been the main source of electricity in the Autonomous Community of Navarre since the advent of this power source. Until 1997, no other source produced as much power as hydraulic energy (Table 1). Since 1997, output has remained stable with regard to prior years, even increasing slightly. However, it is no longer the main source of electricity in Navarre [6].

As from 1995, refurbishment work began on a larger number of power stations that had become obsolete. This managed to increase the energy generated with a minimal environmental impact. The years 1995 and 1997 witnessed the opening of numerous hydropower plants, making the most of former installations. Others were built under the auspices of the Navarre Energy Plan and of the EHN Group. The number of operating power stations has risen by over 100% in 10 years (Fig. 3).

There were 45 installations in 1994, and there are now 110 with an installed power of 174 MW. Over the course of these 20 years, a number of power stations have closed down, although the exact number has not been recorded.

Hydraulic energy (small hydropower) has followed a fairly steady trend at an average of 250 GWh/year. It does not now account for a high percentage (5.29%), yet in 1992 it made up 82% of the energy generated in Navarre, thanks to the full operation of the sole hydroelectric station in Navarre with an installed power in excess of 10 MW, which was commissioned in 1988. The variation recorded in the energy output each year is normal, as it depends on such weather factors as temperature and, above all, the year's rainfall. This is why there are years in which a large amount of electricity is generated, whilst the following year, with the same installed power, there is a smaller output [7].

### 3.1. Meeting 2010 targets

The building of the Itóiz dam and the enlargement of the Yesa reservoir foresee the installation of two new large-scale hydroelectric power stations, whereby Navarre will no

Table 1
Hydroelectric stations and installed power from hydraulic energy

| Year | Installed power (MW) | Annual installed power (MW) | Hydroelectric stations commissioned per year | Hydroelectric stations (aggregate) |
|---|---|---|---|---|
| 1984 | 59.7 | 0.00 | 0 | 36 |
| 1985 | 60.1 | 0.38 | 1 | 37 |
| 1986 | 60.6 | 0.53 | 1 | 38 |
| 1987 | 62.4 | 1.75 | 2 | 40 |
| 1988 | 82.5 | 20.14 | 2 | 42 |
| 1989 | 82.5 | 0.00 | 0 | 42 |
| 1990 | 82.5 | 0.00 | 0 | 42 |
| 1991 | 86.3 | 3.75 | 1 | 43 |
| 1992 | 87.1 | 0.86 | 1 | 44 |
| 1993 | 87.1 | 0.00 | 0 | 44 |
| 1994 | 87.2 | 0.09 | 1 | 45 |
| 1995 | 119.0 | 31.80 | 9 | 54 |
| 1996 | 121.8 | 2.78 | 1 | 55 |
| 1997 | 135.9 | 14.10 | 21 | 76 |
| 1998 | 138.6 | 2.68 | 2 | 78 |
| 1999 | 160.9 | 22.34 | 19 | 97 |
| 2000 | 171.6 | 10.67 | 7 | 104 |
| 2001 | 172.9 | 1.27 | 3 | 107 |
| 2002 | 173.9 | 1.00 | 2 | 109 |
| 2003 | 174.5 | 0.60 | 1 | 110 |
| 2004 | 174.5 | 0.00 | 0 | 110 |

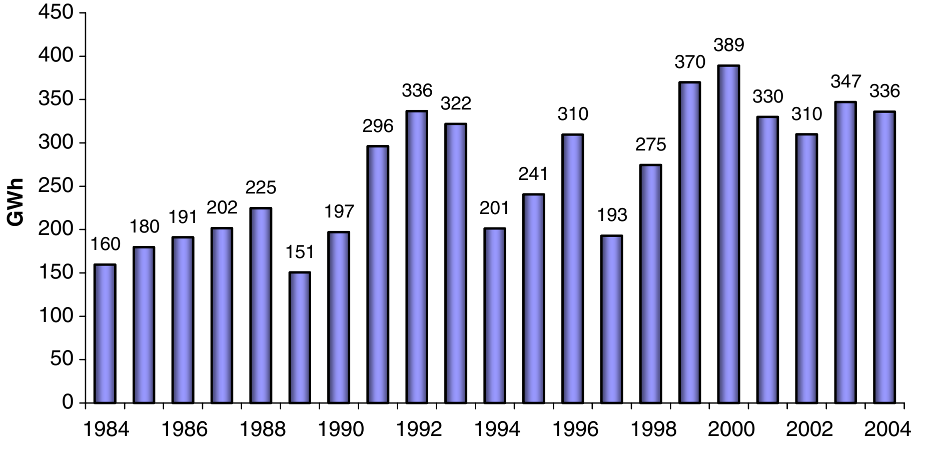



Fig. 3. Electricity production in GWh of hydraulic origin.

longer have just one hydroelectric station with an installed power in excess of 10 MW (El Berbel), but instead there will be three power stations with such specifications. Plans are pending for the Oteiza reservoir, with its corresponding hydroelectric power station.

### 3.1.1. *Itóiz hydroelectric power station*

The Itóiz dam on the River Irati is the most controversial project in the history of Spain's hydraulic policy. It has faced major public opposition from the very start, as well as being the focus of serious economic, environmental, political and moral debate amongst the scientific and technical sectors that have been bold enough to address this problem [8].

The Itóiz dam stands on the River Irati, one of the more attractive features in Navarre's part of the Pyrenees. It is an exceptionally beautiful river, from its headwaters on the Spanish–French border, with the most luxuriant, extensive and best-preserved beech forest in Spain, down to where it joins the River Aragón, after flowing through the stunningly impressive gorge of La Foz de Lumbier. The Itóiz dam project is a protracted history of conflict, and one as yet unresolved. Well-documented information is essential to an understanding not only of what is going on there but also of the mainstays of Spain's current hydraulic policy: the political approach has been to present the Itóiz dam hand-in-hand with the promise of a huge canal that will provide irrigation for over 58,000 ha in the Autonomous Community of Navarre, ensure the supply to another 14,000 ha, generate electricity and guarantee clean water for the majority of Navarre and its industrial sector, besides upholding ecological flow levels in the River Irati.

Power generation will involve the building of two hydroelectric power stations by the publicly owned company Canal de Navarra, SA, which will sell the electricity for distribution. The maximum power output of this hydroelectric station will be 155 GWh/year, a ceiling that will gradually be lowered as the canal comes into operation. When the latter is fully operational, the power station at the foot of the reservoir will be replaced by another at its head, whose output will be lower in accordance with its physical conditions. Annual production may be around 50 GWh/year. The electricity generated by the power station accounts for 4% of Navarre's total electricity consumption. This production will

replace the combustion of 33.34 kt of oil per year and avoid the atmospheric emission of 153 kt of carbon dioxide.

### 3.1.2. Yesa hydroelectric power station

The project addresses the enlargement of the Yesa dam, built on the River Aragón, within the municipal boundaries of Yesa, Sigüés, Mianos and Artieda, in the Autonomous Communities of Navarre and Aragon. It involves the building of a new dam, supported by the current dam for 2/3 of its height, as well as the installation of runoffs and overflows. The reservoir has a total surface area (maximum normal level) of 4408 ha, and a total capacity of 1525 $Hm^3$. The project foresees the construction of two hydroelectric power stations with an installed power of 43.9 MW and an estimated average production of 150 GWh/year, although this output is subject to the preferential use of the dam for supplying drinking water and also for irrigation.

### 3.1.3. Oteiza hydroelectric power station

Oteiza is located in the central area of Navarre, 50 km outside Pamplona. This reservoir is designed to regulate surface water resources on the River Ega, with a view to upholding the supply demand in the Mancomunidad of Montejurra and in the irrigated lands in Lóquiz, Lerín, Carcar, San Adrián and Andosilla. In addition, it is to ensure a minimum flow rate in the lower reaches of the River Ega, estimated to be 1 $m^3/s$. It may also cater for the demand from the future development of an irrigated tract in Navarre, spreading throughout the municipal areas of Lerín, Allo, Andosilla, Funes, Azagra, Carcar, etc. guaranteeing irrigation requirements of 70 $Hm^3$/year, enough to provide for 12,800 ha. Installed power may amount to 15.6 MW, with an annual average output of 35.8 GWh/year. As yet, no date has been set for the construction of this reservoir.

### 3.1.4. Small hydropower plants

According to the Government of Navarre's schedule of projects, between 2005 and 2010, there will be a further 10 MW of installed power in this type of power station, with an average production of 35 GWh/year.

### 3.1.5. Forecasts

In short, it may be affirmed that the Itóiz power station and the small hydropower plants will have been commissioned by 2010. It is unlikely that the Yesa and Oteiza reservoirs will have been built by then.

## 4. Photovoltaic energy

This type of energy is not currently one of the more important in Navarre, nor has it been so in the past. Although this region has great solar potential, it has not been sufficiently exploited. The same applies throughout the rest of Spain. A law has recently been passed that requires the installation of solar panels on new buildings, but these installations are for the self-supply of hot water and little more, for the time being.

In this paper, we are interested in installations that are connected to the grid, and the majority of these are on a small scale (5 kW). In fact, the only plant of major interest in this type of energy in this region is the one in Tudela (1.2 MW installed power) (Figs. 4 and 5).

The year 2003 was a good year for the installation of solar panels. One may think there are a large number of installations, yet they are small extensions, as the majority consists of surface areas of 250 m$^2$, which are approximately equal to an installed power of 5 kW. Before 1996, Navarre had no photovoltaic installations connected to the power grid. This is due to the scant information existing up that moment on photovoltaic energy and its connection to the grid.

The maximum percentage achieved by this type of energy with regard to the total is 0.09%. As stands to reason, this requires major thought and analysis on how to increase this percentage. This type of energy requires a major boost from the public institutions in order to increase its output. Navarre has 41% of all the installations in Spain, and it produces 48% of this energy supplied to Spain's power grid.

Major innovation projects are currently underway, with a concerted effort being made in research. New technologies are being increasingly deployed with ever greater importance in this sector. Solar technologies are turning to robotics and information technologies for

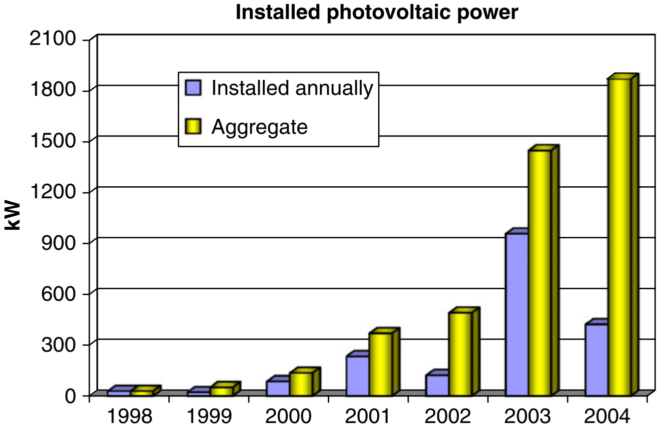



Fig. 4. Installed photovoltaic power.

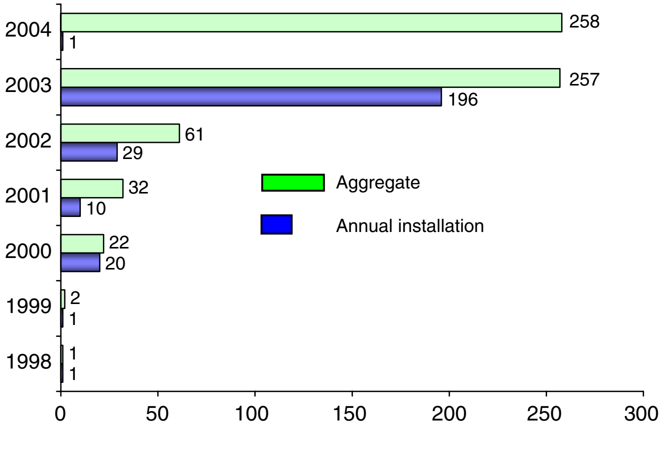



Fig. 5. Number of photovoltaic energy installations.

their control systems. Likewise, new communications technologies lie at the heart of their remote control, thereby rendering them more reliable and efficient, making maintenance easier and providing value added to solar energy systems.

## 5. Biomass

Biomass may be used to generate electricity or gas. This paper focuses on the generation of electricity. It was not until 1997 that this type of energy was first used to generate electricity in this region. That year witnessed the commissioning of the Góngora and Arazuri power plants, both close to the city of Pamplona. The idea was to use the city's urban waste to generate electricity. This installed power is provided solely by six power stations, whereby it is a type of energy that has not been widely developed in Navarre (Fig. 6). The same applies to the rest of Spain [9].

A highlight is the Sangüesa power station, which uses agricultural waste, mainly cereal straw, to generate electricity. It features groundbreaking technology in Spain. Planning is extremely important in the acquisition of the raw material for its subsequent combustion. Following the installation of the Sangüesa plant in 2002, biomass began to make a noticeable contribution to the generation of electricity in Navarre. The production of electricity by means of biomass accounted for 5% of the overall energy generated in 2004. This is a significant percentage, given that this year recorded the highest ever number of GWh in the history of electricity in Navarre. The generation of electricity using biomass is expected to become one of the major energy sources in the future. This allows for the recycling of waste that would otherwise be eliminated, with its energy going unharnessed.

The Navarre renewable energies group, EHN, built Spain's first biodiesel production plant in Caparroso, 40 km to the south of Pamplona. The biodiesel production plant was commissioned in July. The official paperwork for the installation of this plan, developed by

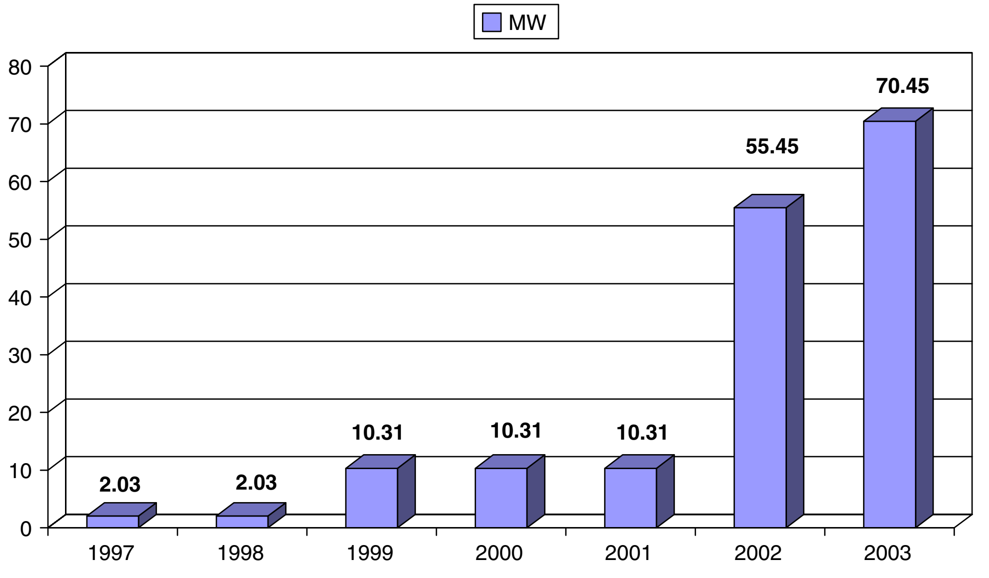



Fig. 6. Aggregate installed power for electricity generated by biomass.

Energía Hidroeléctrica de Navarra, was submitted in 2001 and initial forecasts suggested that construction would be completed by the end of 2003. However, the procedures for obtaining the appropriate licences on the part of the Government of Navarre and the water authority, Confederación Hidrográfica del Ebro, with regard to the efflux of waters, meant that its commissioning was delayed until the middle of last year.

The Caparroso plant will produce 11% of Navarre's biodiesel consumption, which will initially be used for the direct supply of fleets of large vehicles, waste collection lorries or urban transport buses, amongst others. The aim is for this energy scheme to produce 35 kt/year of biodiesel, an output that will be doubled in a second stage. Furthermore, the commissioning of this plant will create between 25 and 30 jobs, thereby constituting a major boost for the area's development. The investment involved in commissioning the plant has amounted to around 30 million euros.

EHN's initial plans involved building a bioethanol plant beside the biodiesel one, and the original schedule of work stated that it would be completed by the first half of 2005. At the time of writing, and despite the fact planning permission was granted at the same time as for the biodiesel plant, there is no information available regarding the exact date on which EHN plans to start building. This project has an approximate cost of 84 million euros, which constitutes a major investment that will undoubtedly require the Administration's backing, through the award of aids and subsidies for its commissioning.

## 6. Hydrogen

The firm Corporación Energía Hidroeléctrica de Navarra (EHN) has embarked upon a research project at the Public University of Navarre with a view to extracting hydrogen from water through the use of electricity provided by wind power. The project involves a laboratory simulation of the conditions of power generation that are particular to a wind farm and the analysis of their effects on an electrolyser, a device that produces hydrogen and oxygen from water through the application of electricity. The technical equipment required consists of an electrolyser—supplied by Stuart Energy Systems, with a rated power of 5 kW and a hydrogen production capacity of 1 $Nm^3/h$. In addition, the equipment includes a 10 kW electronic power converter with current and voltage control, and overall supervision by means of a microprocessor.

## 7. Cogeneration

Until 1991, Navarre had no cogeneration plants installed as such. Prior to that date, the generating facilities were small thermal power stations designed to cater for self-consumption, with any surplus being sold off. Hence the reason why they were not considered to be cogeneration plants and their analysis did not begin until 1991 (Fig. 7).

The installation of cogeneration plants follows a growing trend from 1 year to the next. These data indicate that every year new companies are being set up in Navarre or, in other cases, those already existing are being streamlined and/or enlarged to become more profitable (Fig. 8).

The 1990s saw a major increase in the number of cogeneration installations, yet not in the amount of energy delivered to the grid, as most of the installed power was used for self-consumption, with only surplus being sold. Today, cogeneration plants sell as much electricity as the law permits, and if the company needs more power than that remaining, it

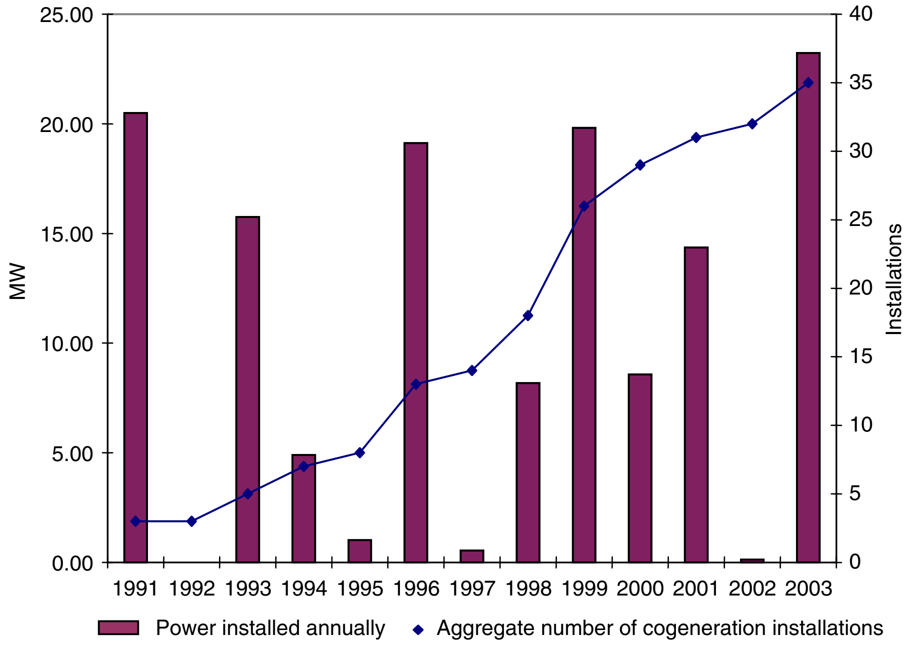



Fig. 7. Power installed on the basis of cogeneration.

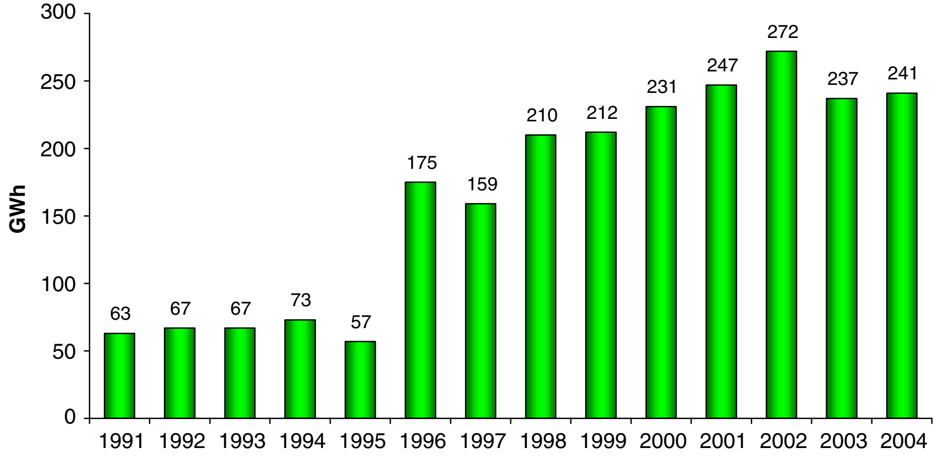



Fig. 8. Annual electricity production in GWh for cogeneration.

is bought from the utility. This is due to the subsidies that are awarded for this type of energy, whereby it is sold for a higher price than it is bought. The energy generated by this method in 1996 amounted to 28% of overall production.

The immediate future is not expected to be bright for this type of energy, given the decrease in subsidies and in the profits generated through its use, due to the increase in costs and the fall in price of the energy sold.

## 8. Combined cycle

This now constitutes an extremely important type of energy generation, given the potential installed in this Autonomous Community. Up until a few years ago, it was believed that Navarre could be self-sufficient in electricity on the basis of renewable sources. In due course, plans were afoot for the installation of two combined cycle power stations in Castejón. These power plants were finally commissioned in 2002 and 2003, respectively. This meant that in 2 years Navarre went from importing energy to generating more than it needed. Each one of the plants has an installed output of 400 MW. The electricity generated by this method in 2004 has amounted to 57% of the total. This fully dismisses the belief held in the last century that Navarre would become self-sufficient with renewable energies.

It is clear that this is going to be the most important type of energy over the coming years. Subsequently, and if the Government permits, the owners of these two plants plan to enlarge them, even doubling the present installed power.

### *8.1. Future prospects*

Elerebro, a 90% subsidiary of Hidrocantábrico, is to invest 195 million euros in the construction of a new combined cycle thermal power station in Castejón (Navarre), beside the current one. Each power plant will have an output of 400 MW and a total of between 55 and 65 jobs will be created, in addition to the almost 600 involved in the building work. It is hoped that all the licenses will have been obtained within 6 months and the development of the site will last for 2 years. This would raise the number of combined cycle power plants in Castejón to three, one of which belongs to Iberdrola.

During the building phase, the company has stressed the fact that this will create 600 jobs and its commissioning will entail an increase in wealth for the entire Autonomous Community. Hidrocantábrico also points out that the requirements for cooling water are considerable less than those for a standard power station, and therefore its thermal impact is minimal, as it avoids heating the river water.

## 9. Tyre processing plant

The firm Terna (Tecnología Energía Recuperada de Navarra) is looking to early 2006 as the possible date for opening, on the Montes de Cierzo industrial estate, a processing plant for used tyres, rubber and vehicle waste that is expected to manage around 14 kt of waste per year. The method to be used is referred to as "flash pyrolysis", which according to the firm "does not involve combustion and, therefore, is not contaminating". The method used by this plant is pioneering not only in Spain and Europe, but also throughout the rest of the world. The system is being tested in a plant in Romsey, in the UK.

The "flash pyrolysis" process allows for the maximum yield from the waste, of up to 90% for obtaining electricity, whereas the remaining sub-product (which depending on the quality amounts to around 10% or 20%) may be used as a building material. Besides pyrolysis, other options that are used for tyres involve landfill, retreading, incineration, recycling and shipment to developing countries, where they have a longer life than in the developed world. Navarre as a whole produces around 5600 t of tyres per year, whereas in Spain as a whole this figure amounts to 300 kt/year. The plant is scheduled to operate

around 8000 h/year, on a continuous basis, the gas will be converted into energy by turbines that will generate an output of 3 MW.

## 10. Compliance with Kyoto and future prospects

For years, the Autonomous Community of Navarre has been undergoing industrial development, which has meant it has recorded high economic growth within Spain and has positioned itself well with regard to other autonomous communities. Navarre's economy in 2004 grew by 3.4%, well above the average for Spain overall (2.7%).

There have only been a couple of years in which Navarre has been below the national GDP (1996 and 1999). This means that the industrial sector is extremely dynamic and consolidated. In view of this, it can be reasonably deduced that Navarre needs a great deal of electricity to uphold the level attained, given that the more a region grows, the greater its energy requirements are.

From 1984 to 1996, the energy generated in Navarre remained practically constant throughout all this time, with a slight upward trend. This generation was produced by two sources, with the more important being hydraulic. As of 1996, the boom in alternative energies meant a new source of income for the regional exchequer, as well as greater development for the autonomous community. The main energy harnessed was wind power. This heralded a sea change in the trend in electricity generation.

From 1996 to 2001, there was a 300% increase in electricity generation in Navarre using these technologies, and a further step forward involved Navarre making the jump to exporting electricity. The year 2000 witnessed the commissioning of biomass power stations that would supply a great deal of electricity, as well as the major wind farms.

Commissioning took place at the end of 2002 of one of the combined cycle power plants in Castejón, whereby there was a 25% increase over 2001 in electricity generated, as it was still not operating at full capacity. The other combined cycle power station came on line in 2003, whereby electricity production recorded growth of 100%.

A feature of 2004 was that no major power stations were opened, yet it was the year in which all the main power stations became fully operational, which meant a 30% growth in production with regard to 2003 (Table 2).

The electricity energy balance is the difference between the amount generated and the amount consumed. We shall consider the consumption of electricity to be a negative value, and generation as a positive one. If the difference is negative, it means that consumption is outpacing production, whereby the shortfall in energy is made up by importing from other autonomous communities or from abroad. For years, Navarre has had to import a large amount of electricity in order to meet demand.

Renewable energies carry a lot of weight in Navarre, which means there can be significant fluctuations depending on the weather. Until 2002, the main sources of energy were renewable, whereby the energy balance may be misleading, as there was no stable energy base. Navarre imported around 2000 GWh/year from 1984 through to 1995. This meant seeking energy alternatives in the region in order to attain self-sufficiency [10,11].

From 1996 onwards, the electricity contributed by wind farms made its presence felt, with the ensuing drop in the import of electricity. There was a falling need for energy from outside and the Government of Navarre's Energy Plans were being fulfilled. It was initially thought that by 2004 Navarre would produce 40% of the energy it consumed and by 2010 this would have risen to 100% of all electricity requirements. All the deadlines were met up

Table 2
Electricity generated over the period 1984–2004, by types

| Year | Hydraulic | Cogen/Therm | Solar | Wind | Biomass | Combined cycle | Total (MWh) |
|---|---|---|---|---|---|---|---|
| 1984 | 159,629 | 38,000 | 0 | 0 | 0 | 0 | 197,629 |
| 1985 | 179,775 | 43,000 | 0 | 0 | 0 | 0 | 222,775 |
| 1986 | 191,005 | 48,000 | 0 | 0 | 0 | 0 | 239,005 |
| 1987 | 201,704 | 52,000 | 0 | 0 | 0 | 0 | 253,704 |
| 1988 | 224,574 | 56,000 | 0 | 0 | 0 | 0 | 280,574 |
| 1989 | 150,575 | 61,000 | 0 | 0 | 0 | 0 | 211,575 |
| 1990 | 197,148 | 62,000 | 0 | 0 | 0 | 0 | 259,148 |
| 1991 | 296,230 | 63,000 | 0 | 0 | 0 | 0 | 359,230 |
| 1992 | 336,496 | 67,000 | 0 | 0 | 0 | 0 | 403,496 |
| 1993 | 321,753 | 67,000 | 0 | 0 | 0 | 0 | 388,753 |
| 1994 | 201,174 | 73,000 | 0 | 44,000 | 0 | 0 | 318,174 |
| 1995 | 240,719 | 57,000 | 0 | 44,000 | 0 | 0 | 341,719 |
| 1996 | 309,742 | 175,000 | 0 | 140,000 | 0 | 0 | 624,742 |
| 1997 | 193,025 | 159,000 | 0 | 249,000 | 1600 | 0 | 602,625 |
| 1998 | 274,536 | 210,000 | 30 | 585,000 | 1600 | 0 | 1,071,166 |
| 1999 | 370,000 | 212,000 | 111 | 756,000 | 3000 | 0 | 1,341,111 |
| 2000 | 389,000 | 231,000 | 111 | 1,004,000 | 3000 | 0 | 1,627,111 |
| 2001 | 330,000 | 247,000 | 260 | 1,436,000 | 3000 | 0 | 2,016,260 |
| 2002 | 310,000 | 272,000 | 2100 | 1,688,000 | 82,000 | 54,000 | 2,408,100 |
| 2003 | 347,000 | 237,000 | 3050 | 1,589,000 | 201,000 | 2,495,000 | 4,872,050 |
| 2004 | 336,000 | 241,000 | 3050 | 1,804,000 | 3,23,000 | 3,643,000 | 6,350,050 |

to 2002, but then the commissioning of the projects involving the combined cycle power plants in Castejón brought forward the scheduled self-sufficiency in energy.

One of the power stations came on line in 2002, leading to a noticeable drop in the imports of electricity. In 2003, Navarre broke even in terms of its energy balance and even moved into the black, thanks to the commissioning of the other combined cycle power station in Castejón. Navarre currently exports 2000 GWh/year, the same amount as it used to import 10 years ago. This provides energy self-sufficiency and generates wealth through the sale of surplus energy (Table 3).

The table shows how up until 2002, Navarre was in the "red" as far as electricity was concerned. Today, besides achieving energy self-sufficiency, there is stable generation with a firm foothold, as 55% of the electricity generated in Navarre corresponds to Combined Cycle. It should be taken into account that maintaining this sound power foothold requires ensuring the gas supply to these power stations.

### 10.1. Energy plan

It is worth noting that since 1996, the year in which the Parliament of Navarre approved its Energy Plan, the Government of Navarre has been furthering and fostering the development of renewable energies (especially wind energy) and energy diversification (through natural gas), with major progress being made in these fields in recent years [12].

IDAE, a public business organisation attached to the Ministry of Industry, and the Government of Navarre subscribed a General Protocol on a Framework Agreement for fostering the development of renewable energies and of those forms of generation that

Table 3
Percentage of electricity (imported/exported)

| Year | Imported (%) | Year | Imported (%) |
|---|---|---|---|
| 1984 | 89.55 | 1995 | 87.58 |
| 1985 | 88.36 | 1996 | 77.22 |
| 1986 | 87.83 | 1997 | 78.87 |
| 1987 | 87.60 | 1998 | 64.52 |
| 1988 | 86.95 | 1999 | 57.03 |
| 1989 | 92.58 | 2000 | 50.98 |
| 1990 | 88.83 | 2001 | 42.41 |
| 1991 | 84.90 | 2002 | 35.80 |
| 1992 | 83.14 | 2003 | 19.12 (exported) |
| 1993 | 83.59 | 2004 | 34.62 (exported) |
| 1994 | 87.55 | | |

contribute to the efficient use and saving of energy. This agreement falls within the remit of the Plan for Fostering Renewable Energies and Spain's 2004–2012 Strategy on Energy Efficiency and Saving.

The regional executive is considering including solar energy and that produced by hydrogen in Navarre's 2005–2010 Energy Plan, which will set forth the guidelines to be followed regarding both renewable energies and infrastructures, transport and distribution, furthermore including an Energy Efficiency and Saving Plan. In terms of renewable energies, it also promotes hydraulic, wind, biomass and waste-generated power.

The development of the Energy Plan, which is currently being drafted, features several objectives that will, in addition, enable compliance with Kyoto targets, a protocol that has already come into force. Insofar as hydraulic energy is concerned, it contemplates new options for exploiting the Yesa and Itóiz reservoirs.

Regarding wind power, it analyses the current state of outgoing supply grids and improvement schemes. At the same time, although no new wind farms are to be authorised, the aim is to pursue the technological development of wind turbines with a higher output than at present, the design of blades with new materials and the development of hybrid systems.

As for biomass, the draft covers the search for, and selection of, new species for obtaining competitive biodiesel, the development of crop techniques for use in energy processes, innovation in the logistics of transport to processing centres and an analysis of options for exploiting biomass (thermal, electrical and biofuels).

It also provides for an improvement in the technology involved in thermal solar energy with a view to enhancing efficiency and reducing costs. Regarding photovoltaic energy, it seeks to integrate photovoltaic systems into building development and encourage the development of panels through the use of new materials. Likewise, the Plan caters for the energy exploitation of waste. Concerning the use of hydrogen as energy, the focus is on improving its availability through storage technology.

Consideration is likewise given to the drafting of an Energy Saving and Efficiency Plan through to 2010, in accordance with the methodology of the National Plan, although adapting it to Navarre's particular circumstances and defining the basic scenarios in terms

Table 4
Forecasted production 2004–2010

| Data 2004–2010 | | |
|---|---|---|
| Type of energy | Installed power (MW) | Production (GWh) |
| Solar | 1.2 | 1.9 |
| Wind | 109 | 238.71 |
| Hydraulic | 41 | 180 |
| Combined cycle | 400 | 2100 |
| Cogeneration | 34 | 101.26 |
| Biomass | 4.17 | 19 |
| Pyrolysis | | 3 |
| Total | | 2643.87 |

of trend and efficiency, as well as the measures to be applied in order to achieve a suitable level of efficiency.

Finally, and insofar as the statutory framework, the Energy Plan provides for the contribution made by schemes for furthering renewable energies and for saving and efficiency measures, the study of the application of emission rights, and the adjustment to the regional legal framework that technically ensures a better ratio between installed power and environmental impact. Based on the above data, display is made of the forecasts for electricity production in Navarre for 2010 (Table 4).

## 11. Conclusions

Over the period 1984–2004, the end consumption of energy has grown at an average annual rate of 4% due to the impetus shown by demand in industry, transport and services. Household consumption, on the other hand, has risen at a significantly lower rate than overall.

Regarding energy sources, there has been a significant change in their structure as a result of the process involving the replacement of oil-based products by natural gas and the increase in the range of sources. The situation in Navarre is characterised by a high consumption of energy per unit of the GDP in comparison to the rest of Spain. Special attention should be paid to the performance of energy intensity in the industrial sector, which in recent years has revealed a slightly upward trend, bearing in mind that it accounts for 46% of the overall demand for end energy and for a significant proportion of the differential observed in the total energy intensity.

The Autonomous Community is home to 31 wind farms. This figure for wind farms is to remain unchanged for a time in response to the current Wind Power Plan, although the power output may change. As has been noted above, the old turbines are to be replaced by more powerful machines, and therefore with a greater output. The power currently installed in the region's wind farms, without including the experimental wind farms, amounts to 883 MW.

Photovoltaic solar energy is also being promoted, although it is hard to imagine that it will ever rival the figures obtained by wind energy. The largest photovoltaic solar

installation in Spain with 400 tracking farms and 1.2 MWp installed. 600 solar farms in four municipalities. Over 100 private solar roofs connected to the grid.

Another major option in renewable energies is provided by small hydropower plants. The Autonomous Community currently has 114 hydraulic installations within its territory. The number of power stations increases each year as a result of Navarre's hydraulic potential. These power stations currently account for an overall installed power of 174 MW.

The latest renewable energy source introduced in Navarre has been the biomass power station in Sangüesa, with an installed power of 25 MW of net electricity, operating for 8000 h/year and consuming 160 kt/year of straw.

The great leap forward that Navarre has taken, from being an importer to an exporter of electricity, has been achieved through the combined cycle power plants. The entire potential is located in the town of Castejón. Today, Navarre exports around 2000 GWh/year, that is, the same amount as it imported 10 years ago. This provides energy self-sufficiency and wealth through the sale of surplus energy. As opposed to the other types of energy that have been described, combined cycle requires a major infrastructure for its operation.

Finally, and with regard to statutory provisions, the Energy Plan provides for the contribution of Development Plans to Renewable Energies and of saving and efficiency measures, the study of the application of emission rights, and the adjustment to the regional framework that technically upholds a better ratio between installed power and environmental impact. If these forecasts are fulfilled, the Autonomous Community of Navarre will generate twice as much as it consumes, posting major returns on the sale of surplus electricity.

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## Interesting information is available on the Internet from the following sites:

Pamplona Energy Agency, www.pamplona.es
European Wind Energy Association, www.ewea.org
Association of Renewable Energy Producers, www.appa.eswww.appa.es
Official Gazette of Navarre, www.BON.htmwww.BON.htm
Official Gazette of Spain, www.boe.eswww.boe.es
Navarre Chamber of Commerce, www.camaranavarra.com
Navarre European Business & Innovation Centre, www.cein.es
National Energy Commission, www.cne.es
Navarre Technology Centre, www.cetenasa.es
Cogeneration, www.cogeneration.org
Development of renewable energies, www.dersa.es
Diario de Navarra, www.diariodenavarra.es
Energía Hidroeléctrica Navarra, www.ehn.es
Renewable energies, www.energias-renovables.com
Eólica Navarra, www.eolicanavarra.es
Gamesa eólica, www.gamesa.es
Government of Navarre, www.navarra.net
Hidrocantábrico, www.h-c.es
Iberdrola, www.iberdrola.es
Energy information, www.infoenergia.com
Geographic information, sitna.cfnavarra.es
Navarre Institute of Statistics, www.cfnavarra.es
National Institute of Statistics, www.ine.es
Institute for Energy Diversification and Saving, www.idae.es
Manuel Torres (wind power), www.mtorres.es
Technology plan, www.plantecnologico.com
Spanish power grid, www.ree.es
Navarre Business Development Company, www.sodena.com
Public University of Navarre, www.unavarra.es